~~P.H. DECKER~~
(1)

INSTRUCTION AND OPERATING MANUAL

FOR

BAIRD ASSOCIATES, INC.

TRANSISTOR TEST SET

Models GP3, GS3, GP4

PROPERTY OF ENGINEERING
TEST EQUIPMENT
CROSLEY, DIV. OF AVCO
ITEM 63 COPY 2

Baird Associates, Inc.
33 University Road
Cambridge 38, Massachusetts

GROUND COMMUNICATIONS SECTION

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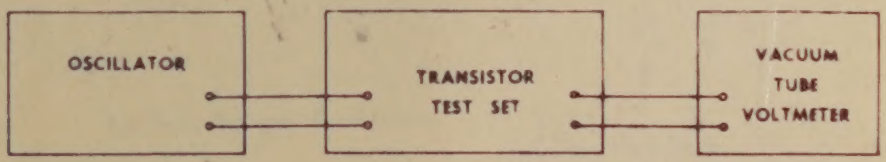
SECTION 1

GENERAL DESCRIPTION

A. The Baird Associates Transistor Test Set is a laboratory instrument designed to measure directly the most commonly used small signal parameters of transistors. It provides the circuit engineer with accurate data, thus facilitating the design of transistor circuitry, not only at low frequencies, but also in the more difficult higher frequency regions.

B. As is shown in the block diagram below, the Test Set is used in conjunction with an external oscillator and a vacuum-tube voltmeter both of which are frequently already available in the user's laboratory. Transistor characteristics may be determined at any frequency between 100



cycles and 1 megacycle for NPN or PNP junction types, triodes and tetrodes, in either grounded-base or grounded-emitter configurations. Point-contact types may also be tested in grounded-base configuration.

C. The measurements are based on the hybrid or "h" parameters and the circuits are basicly simple and straightforward insuring the utmost dependability and reliability of the test results. Absolute accuracy of calibration of the vacuum-tube voltmeter is not necessary (except when switching VTVM scales) since the same VTVM is used both for setting input signal levels and for reading the transistor coefficients.

D. Bias voltages are supplied by long-life batteries thus eliminating troubles due to line variations, complex auxiliary electronic circuits, and spurious noise. Bias conditions are variable over a wide range, although maximum accuracy and convenience of controls has been intentionally centered about the popular 5 or 6 volts collector voltage and 1 ma. emitter current. Both currents and voltages are read on a large polarity-indicating panel meter.

E. Several adaptors are available for the various types of transistor sockets commonly in use as well as a clip-type adaptor for use with transistors having long lead wires.

SECTION 2

SPECIFICATIONS

A. Types of Transistors which can be Analyzed.

Within the D.C. Bias Limitations specified below, all commonly available types of transistors can be tested, for example:

NPN or PNP junction
N or P type point-contact
Surface barrier
Triode and tetrode
Germanium or Silicon

B. D.C. Bias

1. Bias Ranges Available.

	Grounded Base	Grounded Emitter
Emitter Current	0 - 1.2 ma.	0 - 5 ma.
Collector Current	0 - 5 ma.	0 - 5 ma.
Base Current	------	0 - 0.6 ma.
Collector Voltage	0 - 45 volts	0 - 45 volts

2. Bias Meter Scales.

Current Scales 50, 500 μA full scale, plus or minus
1, 5 ma full scale, plus or minus
Voltage Scales 1, 10, 50 V full scale, plus or minus

A jack is provided for plugging in an external meter or galvanometer for measuring values of Ic_o below 2 microamperes.

3. Bias Supply Impedances.

D.C. Source Impedances:
Emitter or Base: 100, 000 ohms
Collector : Variable 5, 000 - 20, 000 ohms, depending on setting of "V_c ADJUST".

A.C. Source Impedances:
Emitter or Base: 100, 000 ohms
Collector : 5, 000 ohms

C. Small Signal Coefficients Measured Directly

		Coefficients for All Frequencies		Coefficients for Low Frequencies				
	Multiplier	Hybrid	Other Names	Hybrid	Other Names	Equivalent T	Good Approximations for Junctions	Measured at 159 kc.
GROUNDED BASE	100 ohms	h_{11_b}	$\frac{1}{y_{11_b}}$		$\frac{1}{g_{11_b}}$	$r_e + r_b(1-\alpha)$		
	1.0	h_{21_b}	α		α	α	α	
	1.0	$1+h_{21_b}$	$1-\alpha$				$1-\alpha$	
	0.1			$1+h_{21_b}$		$1-\alpha$	$1-\alpha$	
	.001	h_{12_b}	γ_b		γ_b			
	10 μmhos	h_{22_b}	$\frac{1}{z_{22_b}}$					C_c
	1 μmho			h_{22_b}	$\frac{1}{r_{22_b}}$	$\frac{1}{r_c + r_b}$	$\frac{1}{r_c}$	
	1000 ohms			$\frac{h_{12_b}}{h_{22_b}}$	r_{12_b}	r_b		
	1 meg			$\frac{1}{h_{22_b}}$	r_{22_b}	$r_c + r_b$	r_e	
GROUNDED EMITTER	100 ohms			h_{11_e}	$\frac{1}{g_{11_e}}$		$r_b + \frac{r_e}{1-\alpha}$	
	1	$+h_{21_e}$	β			$\frac{\alpha}{1-\alpha}$	b	
	1	$1+h_{21_e}$	$1+\beta$			$\frac{1}{1-\alpha}$		
	0.1							
	.001			h_{12_e}	γ_e			
	10 μmhos	h_{22_e}	$\frac{1}{z_{22_e}}$					
	1 μmhos							
	1000 ohms			$10\frac{h_{12_e}}{h_{22_e}}$	$10 r_{12_e}$	$10 r_e$		
	1 meg.			$10\frac{1}{h_{22_e}}$	$10 r_{22_e}$	$10 \times r_c(1-\alpha) + r_e$	$10 \times r_c(1-\alpha)$	

D. Other Coefficients Available.

Alpha Cut-Off Frequency	$f_{\alpha o}$
Beta Cut-Off Frequency	$f_{\beta o}$
Collector Capacitance	C_c
Collector Cut-Off Current	Ic_o
Channel Effect Voltage	V_{ch}

E. Frequency Range of Small-Signal Measurements.

100 c.p.s. to 1 megacycle for grounded base hybrids and β
(See Section 2-F for details)

Note: Since beta cut-off, $f_{\beta o}$, can be measured to 1 mc., alpha cut-off, $f_{\alpha o}$ can usually be computed to over 10 mc. using the approximate relation

$$f_{\alpha o} = \frac{f_{\beta o}}{1 - \alpha}$$

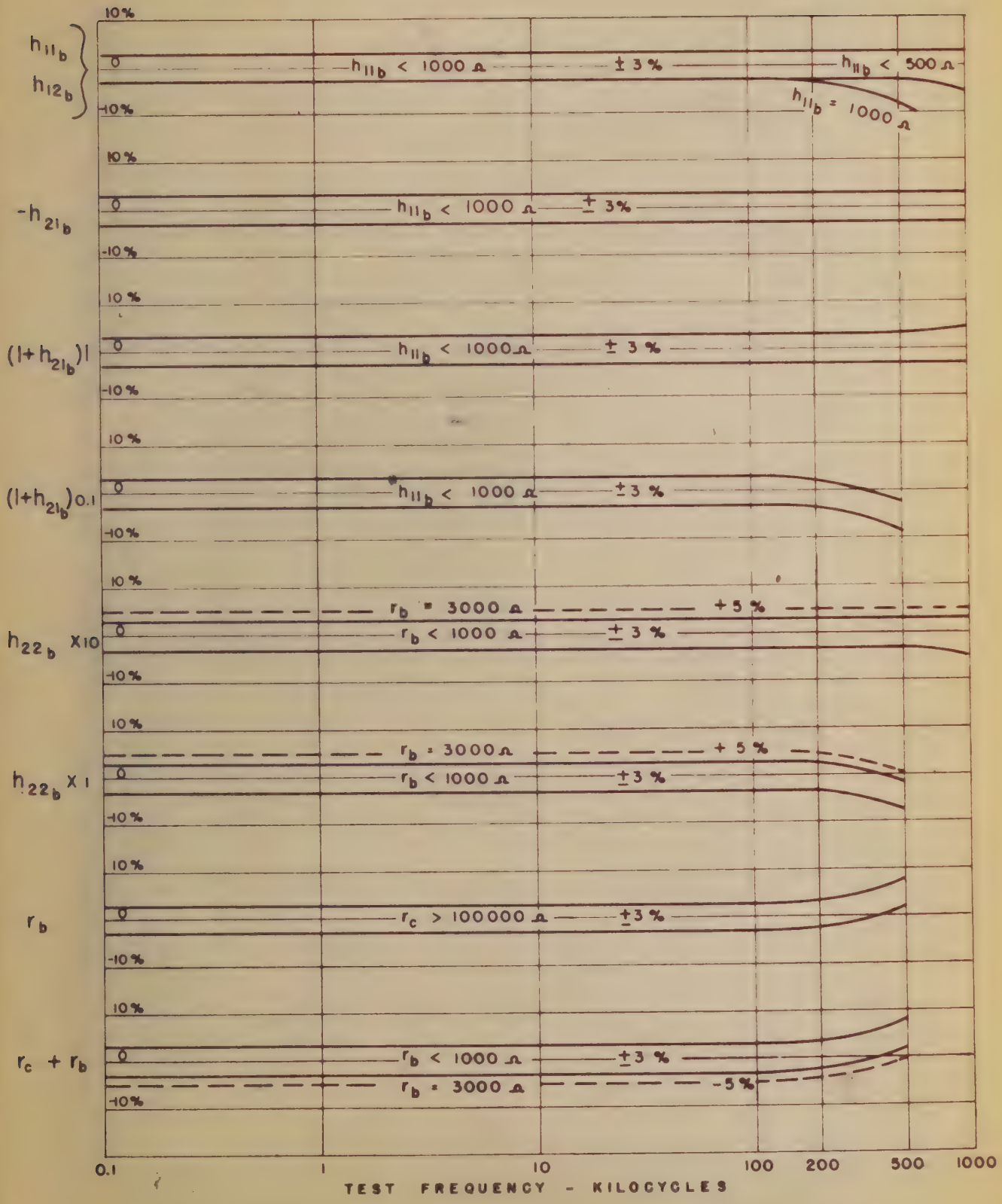
F. RANGE OF PARAMETERS AND ACCURACY. (Exclusive of VTVM Errors.)

1. Nominal Limits

Parameter	X	Measurable Range	Low-Frequency Accuracy	High Frequency Accuracy	Limitations For Stated Accuracy
h_{11b}		10 - 1000 ohms	3% to 500 kc	5% to 1 mc	h_{11b} <500 Ω
$-h_{21b}$		0.1 - 10	3% to 1 mc	3% to 1 mc	h_{11b} <1000 Ω
$1+h_{21b}$	×1.0	0.1 - 1	3% to 500 kc	5% to 1 mc	h_{11b} <1000 Ω
$1+h_{12b}$	×0.1	.01 - 0.1	3% to 100 kc	5% to 300 kc	h_{11b} <1000 Ω
h_{12b}		.0001 - 1.0	3% to 500 kc	5% to 1 mc	h_{11b} <500 Ω
h_{22b}	×10	1 - 1000 μmhos	3% to 500 kc	5% to 1 mc	r_b <1000 Ω
h_{22b}	×1	0.1 - 10 μmhos	3% to 100 kc	5% to 300 kc	r_b <1000 Ω
r_b		100 - 5000 ohms	3% to 100 kc	5% to 300 kc	r_c >100 KΩ
r_c+r_b		0.1 - 10 meg.	3% to 100 kc	5% to 300 kc	r_b <1000 Ω
h_{11e}		10 - 3000 ohms	5% to 50 kc		h_{11e} <3000 Ω
$+h_{21e}$		1 - 1000	5% to 1 mc	5% to 1 mc	h_{11e} <3000 Ω
$1+h_{21e}$	×1	1 - 1000	5% to 1 mc	5% to 1 mc	h_{11e} <3000 Ω
h_{12e}		.0001 - 1.0	5% to 50 kc		h_{11e} <3000 Ω
h_{22e}	×10	1 - 300 μmhos	5% to 500 kc		h_{22e} <300 μmhos and βr_e <3000 Ω
r_e		10 - 1000 ohms	5% to 100 kc		r_b <3000 Ω and h_{11e} <3000 Ω
r_{22e}		10K - 1 meg.	5% to 500 kc		r_{22e} >3000 Ω and βr_e <3000 Ω

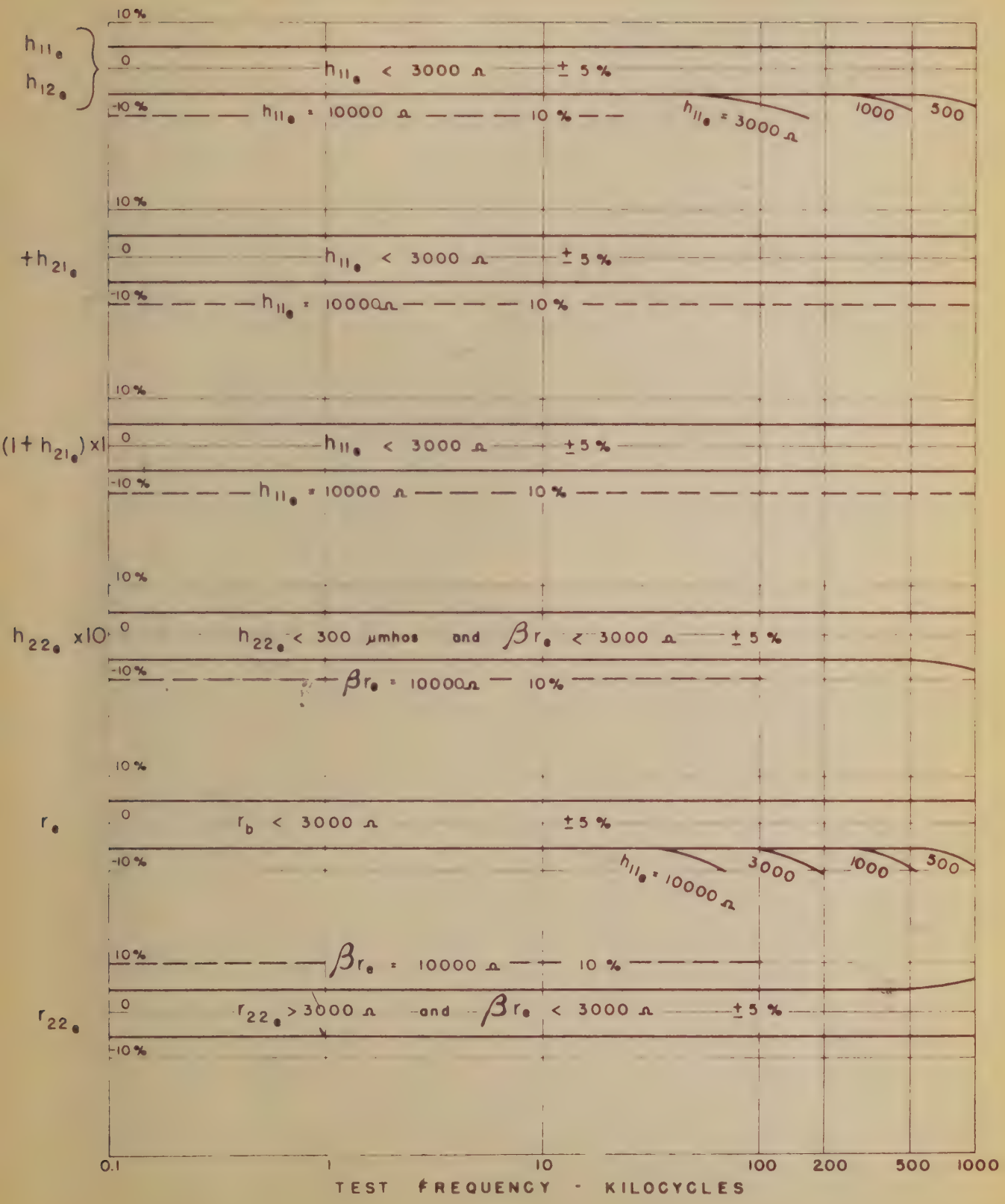
2. Accuracy vs. Frequency

a. Grounded Base Parameters



2. Accuracy vs. Frequency

b. Grounded Emitter Parameters



G. Adaptors

One adaptor with socket for transistors with standard .048 inches and .144 inches pin spacing is supplied. (Model HS1)

Also available are adaptors as follows:

Model HL1	General Purpose Adaptor with low capacity spring clips for transistors with long leads.
Model HM1	Texas Instruments Junction Tetrodes
Model HN1	Raytheon CK 720 Series
Model HP1	CBS Hytron Types, P.C. or Junction
Model HQ1	Western Electric Point Contact Types
Model HR1	GE Point Contact Types

Other Adaptors are available on special order to take specified transistor types.

Note: The General Radio Type 561-415-2 spring clip adaptor may also be used in the Transistor Test Set without modification (for low frequency tests only).

H. Accessory Equipment Required.

Oscillator:

Output up to 10 volts should be available (no load).
Output impedance 600 ohms or less recommended. (Higher values are permissable but operation may be less convenient.)
Frequency range to cover tests desired or 100 cps. to 1 mc.

Vacuum-Tube Voltmeter:

Sensitivity .001 volts full scale with other ranges in decades up to 10 volts full scale.
Input impedance at least 1/2 megohm shunted by not more than 25 $\mu\mu$f for tests at 1 mc. For lower frequencies proportionally more capacitance can be tolerated.

I. Optional Accessory Equipment for Special Tests.

Cathode Ray Oscilloscope:
Useful for monitoring transistor output signal for distortion or noise in cases of unusual bias conditions or high-noise transistors.

J. Models Available.

GP3 - Deluxe Cabinet Model
GP4 - Standard Cabinet Model
GS3 - Rack Mounting Model

K. Power Supply

Model GP3 - Four 45V Batteries, Burgess Type 2308 or equivalent.
(Probable life in normal use over 1 year.)
Models GS3 and GP4 - Four 45V Batteries, Burgess Type 5308 or equivalent.
(Probable life in normal use 3 to 6 months or more.)

L. Overall Dimensions

Model GP3 - 24" long x 15" high x 15" deep, maximum.
Model GP4 - 22" long x 13" high x 10" deep, maximum.
Model GS3 - Panel 19" x 10-1/2", depth 9" maximum.

M. Weight

Model GP3 - 75 lbs. net. Shipping weight 150 lbs.
Model GP4 - 40 lbs. net. Shipping weight 70 lbs.
Model GS3 - 30 lbs. net. Shipping weight 60 lbs.

SECTION 3

OPERATION

A. Unpacking and Setting Up.

1. The battery compartment is accessible in the Model GP3 by unscrewing the top of the cabinet, in the Model GP4 by unscrewing the rear panel, and in the Model GS3 by means of the hinged door in the rear.

   Check terminals of batteries to see that they have not loosened during shipment.

2. An oscillator (not supplied, see Section 2-H) should be connected to the OSC IN terminals (the black terminal is the grounded terminal).

3. A vacuum tube voltmeter (not supplied, see Section 2-H) should be connected to the AC VTVM connector with the coaxial cable provided.

B. Explanation of Panel Controls.

1. NPN - PNP (S1)

   Polarity-reversing switch for bias.
   For point-contact transistors, set to PNP position.

2. GROUNDED EMITTER - GROUNDED BASE (S3)

   Switches transistor configuration to either grounded base (for h_{11b} h_{12b} etc.) or grounded emitter (for h_{11e} h_{12e} etc.)

3. BIAS ON - OFF - I_{co} (S2)

   In OFF position, biases are removed from transistor socket and battery drain is zero. In BIAS ON, biases are applied to transistor (even if meter is not indicating). In I_{co} the collector has voltage applied but the emitter is open.

4. HIGH - LOW (S12)

   Reduces voltage from OSC in LOW position, for fine control in setting of E_R.

5. BIAS METER (M1)

   Indicates D.C. bias voltage and currents and their polarity when proper lever switch is pushed.

6. EXTERNAL BIAS METER JACK (J2)

A phone plug connected to a meter or galvanometer plugged in here automatically disconnects the BIAS meter, and inserts the external meter for measuring I_{co} below 2 microamperes.

7. I_e ADJUST (R5)

Sets I_e to desired value in conjunction with lever switches and BIAS meter in grounded base configuration.

8. I_b ADJUST (R10)

Sets I_b to obtain desired I_c in grounded emitter configuration.

9. V_c ADJUST (R9)

Control for setting V_c to desired value.

10. PUSH TO READ BIAS (S6 to S11)

Six spring-return lever switches used singly in conjunction with the BIAS meter to select meter range and to indicate bias voltage or current. In the center or neutral positions the BIAS meter is out of the transistor circuit but the biases are still applied. When a key is depressed the existing bias is indicated on the meter and may be varied by the I_1 or V_1 ADJUST controls.

Note: I_e is the D.C. emitter current in GROUNDED BASE.

I_b is the D.C. base current in GROUNDED EMITTER.

V_e is the D.C. emitter to base voltage in GROUNDED BASE.

V_b is the D.C. base to emitter voltage in GROUNDED EMITTER.

I_c is the D.C. collector current.

V_c is the D.C. collector voltage.

11. COEFFICIENT SELECTOR (S5)

This switch selects the desired coefficient in conjunction with the GROUNDED EMITTER-GROUNDED BASE switch. The latter determines whether the coefficient will be read on the GROUNDED EMITTER ring or on the GROUNDED BASE ring.

For coefficients on the HYBRID ring the GE-GB switch adds, in effect, the subscript e or b to the indicated h-parameter. (See chart Section 2-C). Hence, this ring gives two complete series of h-coefficients. A few less-used coefficients not marked on the panel are also obtainable by direct reading as shown in the chart of Section 2-C above. Simply set selector to a corresponding parameter shown in the same horizontal row of the chart.

The outer ring indicates the multiplying factor used in conjunction with the VTVM reading, E_X.

The rectangle around the coefficient h_{11}, h_{12}, $1+h_{12}$, h_{21}, and h_{22} indicates roughly that these are the coefficients which can be read to 1 mc. whereas the others have individual frequency limits (See Chart 2-F).

12. ER - EX (S4)

In the center position the circuit is set for adjusting the oscillator signal level to the reference value E_R, usually 1 millivolt on the external Vacuum Tube Voltmeter.

In the down position the circuit is set for reading the value of the coefficient (called E_X before decimal point and dimensional units have been determined on the Vacuum Tube Voltmeter.

13. TRANSISTOR ADAPTOR SOCKET

The adaptor plugs into this octal socket on the panel.

SECTION 4

STEP-BY-STEP MEASUREMENT PROCEDURE

A. Measurement of A.C. Coefficients

1. Plug proper adaptor into octal socket.
2. Check to see that BIAS ON switch is in OFF position.

   CAUTION: Always have this switch OFF while inserting or removing transistors. Failure to do so may damage the transistor.

3. Plug transistor into socket.
4. Set NPN-PNP switch to required position. (Refer to manufacturer's data.)
5. Set GROUNDED EMITTER-GROUNDED BASE switch to configuration required depending on coefficients desired. (See chart Section 2-C.)
6. Turn BIAS ON-OFF switch to BIAS ON position.
7. Set D.C. bias currents as follows:
   a. For Grounded Base connection:
      (1) Set emitter current to desired value by I_e ADJUST control while pushing proper I_e lever switch to indicate current on BIAS meter. Then release I_e switch.

      CAUTION: Avoid depressing red I_e or I_c lever switches to 50μA positions accidentially or unless it is known that current will be within 50μA range, for damage to meter may result.

      (2) Set collector voltage to desired value by V_c ADJUST control while pushing V_c lever switch to the appropriate range to indicate voltage on BIAS meter. Then release V_c switch and the biasing is complete.
      (3) V_e may now be read, if desired, using V_e switch.

   b. For Grounded Emitter connection:
      (1) Check to be sure that the COEFFICIENT SELECTOR is not in either the $(1+h_{21}) \times 0.1$ or the $h_{22} \times 1$ position which are blank in the GROUNDED EMITTER ring of the dial.
      (2) Set up desired I_e and V_c in GROUNDED BASE configuration.
      (3) Observe I_c by pressing appropriate I_c lever switch.
      (4) Switch to GROUNDED EMITTER.
      (5) Using I_b ADJUST control while depressing I_c lever switch, readjust I_c to value observed under (3).
      (6) The biasing in now complete and the transistor may be switched from G.E. to G.B. or back again to G.E. without changing bias conditions.
      (7) The base current I_b may now be measured, if desired, using the red I_b switch.
      (8) The base voltage V_b may be read, using the V_b switch.

      Note: If transistor is being operated near its maximum rated dissipation, the biases can be expected to drift due to internal heating in the transistor until equilibrium is reached. This is especially true in case of grounded emitter operation and may necessitate a reduction of power input to obtain reproducible readings.
8. Set COEFFICIENT SELECTOR to desired position (See chart Section 2-C for additional coefficients not listed on dial).

9. Set external oscillator to desired frequency.
10. Adjust amplitude of oscillator signal (by oscillator's output control) until external VTVM reading is 1 millivolt, with the E_R-E_X switch in the E_R or center position. Use the LOW position of the HIGH-LOW switch if amplitude control on oscillator is too coarse at low end.
11. Depress the E_R-E_X switch to E_R position and read E_X in millivolts on the VTVM. If necessary to switch VTVM to a different scale, make the proper decimal point correction.
12. Divide E_X (in millivolts) by E_R (in millivolts), giving E_X/E_R the magnitude of the desired coefficient, without its units.
13. Multiply E_X/E_R by the figure in the outer ring of the COEFFICIENT SELECTOR dial, giving the value of the coefficient together with its units. (Note that h_{21}, α, β, $1+h_{21}$ and γ are dimensionless.

B. Example of measurement of a coefficient:
Let us say the coefficient to be measured is $1 - \alpha$
1. Set the COEFFICIENT SELECTOR to the $1-\alpha$ position which has 0.1 in the outer ring (for low frequencies).
2. With E_R-E_X switch in E_R position; set oscillator level until the VTVM reads 1 millivolt (full scale).
3. Depress the switch to E_X position.
4. Read 0.45 millivolts on the same scale.
5. Hence $E_X/E_R = 0.45/1 = 0.45$.
6. Multiply by the outer ring multiplying factor which is 0.1, giving .045 for $1-\alpha$. Hence $\alpha = .955$.

C. Special Notes.
1. h_{21} or α
The direct measurement of α in this position will be accurate to approximately 3%. For more accurate values of α use the $(1+h_{21})\times 0.1$ position, giving 0.3% accuracy.
2. $1+h_{21}$ or $1-\alpha$
The X 0.1 position is generally used at low frequencies and for values of α between 0.90 and 0.99 and the X 1 position for α less that 0.90. The X 0.1 position is not used in grounded emitter.
3. h_{22}
The X 1 position is generally used at low frequencies and for values of h_{22b} between 0.1 and 2 μmhos and the X10 position for high frequencies or for point-contact transistors. The X 1 position is not used in grounded emitter.
4. r_e, r_b, $r_c + r_b$
It will be necessary to readjust the oscillator amplitude for each of these positions and for each transistor.
For r_e, switching over to GROUNDED EMITTER will necessitate re-establishing the D.C. biases. (See Section 4-A-7b.)
The quantity read directly in the r_e position is actually 10 r_e, as shown on the dial, so the reading must be divided by 10 in addition to multiplying by 1000 ohms. In other words, the multiplier for r_e is 100 ohms.
With junction transistors $r_c + r_b$ will be equal to r_c to better than 1% accuracy since $r_b \ll r_c$.

5. Distortion:
The peak-to-peak signal swing in the collector circuit should not be allowed to exceed the D.C. bias voltage on the collector or distortion and consequent inaccurate readings will result. With the great majority of transistors the recommended reference voltage of 1 millivolt will not result in distortion unless the D.C. collector voltage is less than 3 volts, except in measuring r_b or $r_c + r_b$. For these coefficients, the collector voltage should always be maintained at a voltage no less than 3 times r_c (where r_c is in megohms). Alternatively, E_R may be reduced to the point where distortion does not occur as seen by an oscilloscope monitoring the VTVM output. Parameter readings must then be divided by the same factor by which E_R was reduced below the standard value of 1 millivolt.

6. Noise:
If readings are suspected of being inaccurate due to high noise, check by turning off signal. If reading does not drop 10 to 1, a higher value of E_R should be used, and the readings corrected accordingly.

D. Measurement of Collector Capacitance, C_c.
Direct readings may be obtained on the VTVM dial as follows:
1. Follow procedure of Section 4-A, 1 through 7, as usual, using GROUNDED BASE configuration.
2. Set oscillator frequency to 159 KC.
3. Set the COEFFICIENT SELECTOR TO C_c (same as $h_{22} \times 10$).
4. Set VTVM, E_R, to 1 millivolt.
5. Depress E_R-E_X switch to E_X and read collector capacitance on VTVM, reading $\mu\mu$f in place of μmhos for units.
6. Check to see if true capacitance is being measured by dropping frequency to some low value, say 100 to 1000 cycles. If h_{22} goes down 4 times or more in value, (as it will with most transistors) the capacitance measured was accurate.

Note: The adaptor is specially designed for low capacitance.
The stray capacitance between collector and base at the transistor socket is approximately 0.1 $\mu\mu$f.

E. Measurement of Alpha Cut-Off, $f_{\alpha o}$ and Beta Cut-Off $f_{\beta o}$
1. Measure α or β at low frequency in usual way, using the h_{21} position.
2. Increase frequency until α or β drops 3db or to 0.707 times its low frequency value.
3. Read $f_{\alpha o}$ or $f_{\beta o}$ on oscillator frequency dial.

F. Measurement of I_{co} (Collector Cut-Off Current, I_c with $I_e = 0$)
1. Follow steps 1 through 4 in Section 4-A above.
2. Set to GROUNDED BASE configuration.
3. Turn BIAS ON-OFF-I_{co} switch to I_{co}.
4. Adjust V_c to desired voltage while depressing V_c lever switch
5. Throw red I_c switch first to 500 μA, then to 50 μA, and read I_{co} on BIAS meter.
6. An external sensitive microammeter or galvanometer may be plugged into the EXTERNAL BIAS METER jack to read I_{co} below 2 microamperes. Use a 2-wire phone plug wired to the external meter. Use the 50μA position of I_c which removes all shunts.

G. Measurement of V_{ch} (Channel Effect Voltage, V_e with $I_e = 0$).
1. Follow steps 1 through 4, Section 4-A above.
2. Set to GROUNDED BASE configuration.
3. Turn BIAS ON-OFF-I_{co} switch to I_{co}.
4. Adjust V_c to desired voltage while depressing V_c lever switch.
5. Depress V_e lever switch and read V_{ch} on BIAS meter.

H. Typical Values of Low Frequency Parameters for Junction Transistors (for bias of I_e = 1 ma., V_c = 5 volts.)

h_{11b}	25 - 100 ohms	r_b	100 - 1000 ohms
$-h_{21b}$	0.90 - .99	r_e	10 - 50 ohms
$1+h_{21b}$	.01 - .10	r_c	0.5 - 5 meg.
h_{12b}	.0001 - .001		
h_{22b}	0.2 - 2.0 μ mhos	C_c	10 - 50 $\mu\mu$f
h_{11e}	500 - 3000 ohms	$f_{\alpha o}$	0.5 - 5 mc
$+h_{21e}$	10 - 100		
$1+h_{21e}$	10 - 100		
h_{12e}	.0005 - .010	I_{co}	1 - 15 μA
h_{22e}	5 - 100 μmhos	V_{ch}	.01 -.30 volts

I. Point-contact Transistor A.C. Coefficients

Hybrid coefficients for point-contact transistors may be measured in grounded base configuration.

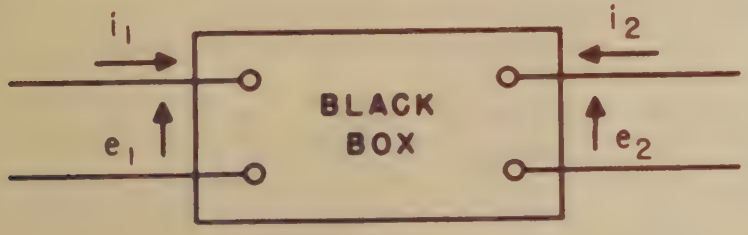
Since point-contact types are almost always N-type, set the NPN-PNP switch to PNP. The biasing and measuring procedure will be standard except that the sign of g_{11}^{-1} may be either positive or negative, and the polarity may be determined by an oscilloscope, checking for reversal between the phase of E_X and the phase of E_R.

SECTION 5

THEORY OF OPERATION

A. Hybrid Parameters.

1. It may be shown (1) that a transistor operating linearly under small signal conditions may be represented by a 4-terminal network element or "black box".



The changes of voltage and current about a given operating point or set of D.C. biases may be represented in various ways using open or short-circuited impedance or admittance parameters. From the point of view of measureability, a set of parameters involving a combination of both open-circuited and short-circuited conditions, called "hybrid" parameters (2), has been found useful in junction transistor analysis.

2. The hybrids are defined as the coefficients in the following equations for the "black box" above

$$e_1 = h_{11}\, i_1 + h_{12}\, e_2$$

$$i_2 = h_{21}\, i_1 + h_{22}\, e_2$$

From these equations it is seen, by successively setting e_2 and i_1 equal to zero (that is, an A.C. short-circuited output and an A.C. open-circuited input respectively) in each equation, that

$$h_{11} = \left.\frac{e_1}{i_1}\right|_{e_2=0}$$ = input impedance with output short-circuited

$$h_{12} = \left.\frac{e_1}{e_2}\right|_{i_1=0}$$ = voltage feedback ratio with input open-circuited

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{e_2=0}$$ = current amplification with output short-circuited

$$h_{22} = \left.\frac{i_2}{e_2}\right|_{i_1=0}$$ = output admittance with input open-circuited

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1. "Transistor Audio Amplifiers" by R.F. Shea, John Wiley & Sons, 1955. Chapter 2.
2. "Communication Networks", 2nd Edition, by E.A. Guillemin, John Wiley & Sons, 1952.

It is upon the above definitions that the principle of operation of the Baird Associates Transistor Test Set is based.

3. It follows that there are two complete sets of these hybrid parameters depending upon whether the transistor is connected in grounded-base or grounded-emitter configuration. The subscripts "b" and "e" are used with the h-parameters to define this configuration.

4. A chart showing simplified circuits of the ones used for measuring the parameters is given in Section 5-A-6 in order to clarify the theory of operation of the Transistor Test Set. (Blocking condensers, D.C. bias supplies, and bias metering circuits are omitted for simplicity.) It will be seen that the circuits closely follow the definitions of the h-parameters as stated in section 5-A-2. The 100K/100-ohm voltage dividers allow setting of a 1-volt signal level using the .001 volt scale of the vacuum-tube voltmeter, thus minimizing the amount of decade switching between the setting of E_R and the measuring of E_X.

   A fifth hybrid parameter, $1 + h_{21}$, is added to increase the accuracy of determination of h_{21}. The quantity $1 + h_{21}$ (or $1 - \alpha$) also appears frequently in equivalent circuit computations. If h_{21} (or $-\alpha$) is greater than 0.9, the accuracy with which it may be measured is more than 10 times greater using the quantity $1+ h_{21}$ as the directly measured parameter.

   For h_{11}, h_{21} and $1 + h_{21}$, the input signal is 10 microamperes. For h_{12} and h_{22} the applied signal is 1 volt. These values are suitable for most transistors, but if unusually low values of bias are used distortion may result and the reference E_R will have to be reduced. (See Section 4-C-5) On the other hand to measure transistors having h_{21} greater than 0.99 in the $(1 + h_{21}) \times 0.1$ position the reference may be increased in order to get a reading of E_X.

5. In the chart, section 2-C, are shown equivalent names (3) for the hybrid parameters, for example:

$$h_{11b} = \frac{1}{y_{11b}} \doteq \text{(for low frequencies)} \frac{1}{g_{11b}}$$

$$h_{12b} = \mu_b$$

$$-h_{21b} = \alpha \qquad +h_{21e} = \beta$$

$$1+h_{21b} = 1- \alpha$$

$$h_{22b} = \frac{1}{z_{22b}} = \text{(for low frequencies)} \frac{1}{r_{22b}}$$

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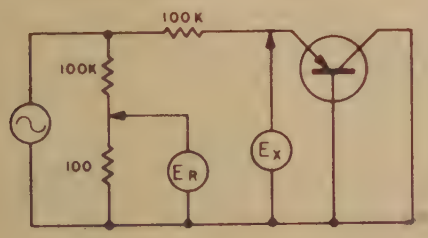
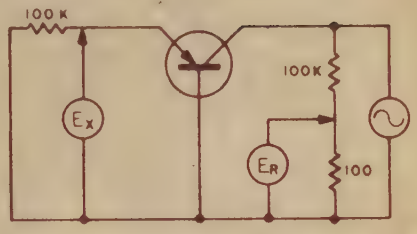
3. Knight, Johnson and Holt, "Measurement of the Small-Signal Parameters of Transistors", Proc. I.R.E., Vol. 41, No. 8, p. 984, August 1953.

6. Simplified Measuring Circuits of the Transistor Test Set

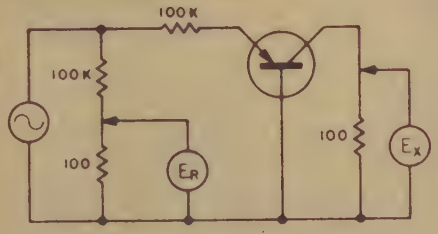
h_{11}



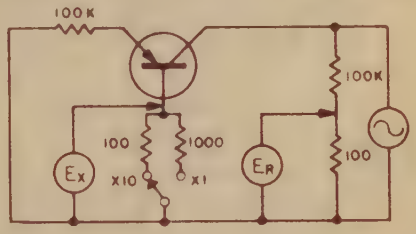
h_{12}



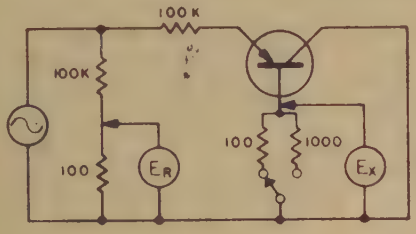
h_{21}



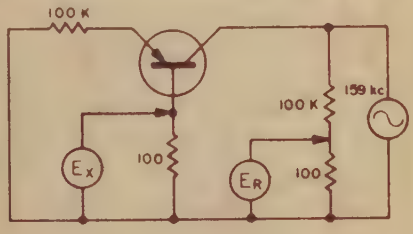
h_{22}



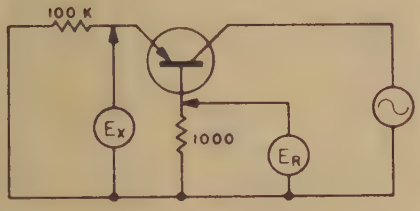
$1 + h_{21}$



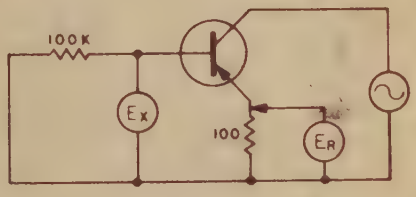
C_c



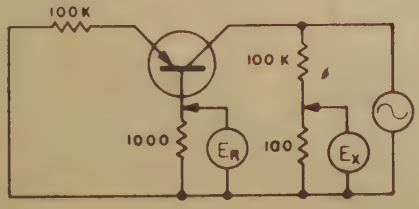
r_b



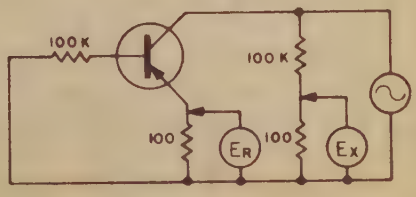
r_e



$r_c + r_b$

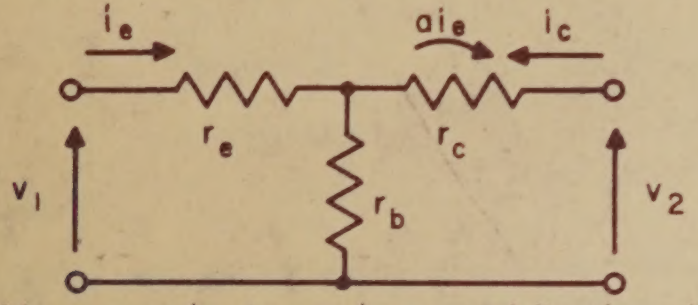


r_{22_e}



B. Equivalent T Circuit Parameters

1. One of the most common equivalent circuits of a transistor is that using the current generator representation shown below: (4)



2. The quantities r_e, r_b and $r_c + r_b$ can be measured directly on the Transistor Test Set as shown in the chart, Section 2-C. Since for junction transistors r_b is less than one thousandth of r_c, the latter may be read directly with good accuracy.

3. The simplified measuring circuits for these parameters are shown in the chart, Section 5-A-6. For r_b and r_c a reference current of 1 microampere is used in the collector circuit, and for r_e it is 10 microamperes. If excessive noise is present, errors in readings may result. Within the limitations imposed by collector circuit distortion, the reference signal E_R may then be increased and the readings compensated proportionately (See Section 4-C-5).

C. Other A.C. Parameters

1. Collector capacitance C_c, the effective capacitance between collector and base of the transistor is measured directly in the $h_{22b} \times 10$ position, using f = 159Kc. The open-circuited output admittance assuming C_c in parallel with r_{22} is

$$h_{22} = \frac{1}{r_{22}} + j\omega C$$

At frequencies high enough such that

$$\omega C_c \gg \frac{1}{r_{22}} \quad , \; h_{22} = \omega C_c$$

If f = 159000 c.p.s., $\omega = 10^6$

then $h_{22} = C_c \times 10^6 = C_c \; (\mu\mu f)$

or the magnitude of h_{22} as read will be equal to the capacitance. (The multiplier $\times 10$ still applies, so the reading will be $\times 10 \; \mu\mu f$). Neglecting $\frac{1}{r_{22}}$ will cause less than 5% error in C_c provided r_{22} (in megohms) $\times$ C_c (in $\mu\mu f$) is greater than 3.

2. The low-frequency parameters r_{12b} and r_{12e} are equal to r_b and r_e respectively and so are directly measurable. Similarly $r_{22b} = r_c + r_b$, and in the corresponding grounded emitter position r_{22e} may be read directly. The other r-parameters r_{11} and r_{12} may be easily computed.

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4. "Transistor Audio Amplifiers", by R.F. Shea, John Wiley and Sons, 1955, Chapter 2.

SECTION 6

MAINTENANCE

A. Battery Replacement

1. The emitter battery (three 45-volt batteries in series) should be replaced when it is no longer possible to set I_e to 1 ma with a (good) transistor in the socket and the I_e adjust control at its maximum setting.

2. The collector battery (single 45-volt battery) should be replaced when the bias meter reads 30 volts or less when the V_c adjust control is at its maximum setting and no transistor is in the socket.

3. CAUTION: Do not leave low or dead batteries in case as chemical action may damage the instrument.

4. Batteries Used:

   Model GP3 - Burgess Type 2308 or equivalent.
   Models GP4, GS3 - Burgess Type 5308 or equivalent.

5. Batteries are replaced in the Model GP3 by unscrewing and removing the top panel of the cabinet and then removing the cover of the battery holder.

   In the Model GP4, batteries are reached by removing the back panel of the cabinet.

   In the Model GS3, access to batteries is through a hinged door in the rear.

   CAUTION: Be sure bias switch is OFF when removing batteries.